Total Ear Reconstruction Using Porous Polyethylene

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Abstract

Total ear reconstruction has been approached by several techniques involving autologous graft, prosthetic implant, and alloplastic implant options. Recent studies have shown the superiority of porous polyethylene (Medpor, Porex Surgical) reconstruction over autologous reconstruction based on improved aesthetic results, earlier age of intervention, shorter surgery times, fewer number of required procedures, and a simpler postoperative recovery process. A durable and permanent option for total ear reconstruction, like Medpor, can help alleviate the cosmetic concerns that patients with auricular deformities may be burdened with on a daily basis. In this article, the authors discuss the advantages of Medpor-based ear reconstruction and discuss recent advances in the surgical techniques involved, such as harvesting a temporoparietal fascia flap and full-thickness skin graft to adequately cover the Medpor framework and decrease extrusion rates.

Keywords
- ear reconstruction
- microtia
- polyethylene
- Medpor
- temporoparietal fascia flap

The face is one of the most visible and recognizable parts of the body, so soft tissue deficiencies, functional issues such as wearing glasses, and skeletal defects can be especially upsetting to patients. External ear defects in particular can be incredibly displeasing to children as they are highly noticeable and lead to social ridicule. Congenital auricular malformations result from aberrant embryological development of the first and second branchial arches and include anotia, microtia, cup ear, and protruding ear.[1] Acquired deformities occur in children or adults and can be due to trauma, burns, cancer resection, or animal bites. Total ear reconstruction is implemented to provide favorable cosmesis and functional outcomes for patients. In children with microtia who often have concomitant conductive hearing loss and possible speech delay, total ear reconstruction and complementary procedures address both hearing impairments and symmetric concerns to optimize the child's future development.[1]

Several modalities are available for total ear reconstruction of microtia: autologous costal cartilage, silastic frameworks, porous polyethylene implants, and prosthetic implants.[2] One of the initial management decisions a surgeon needs to make is to determine whether to use autologous, alloplastic, or prosthetic material for the ear construct depending on the severity of microtia and functional goals following surgical correction. Autologous reconstruction of microtia with a sculpted costochondral graft is classically performed in staged procedures, as described by Tanzer,[3] Brent,[4] Nagata,[5] and Firmin.[6] Alloplastic implants have gained more acceptance as another option for ear reconstruction because alloplastic reconstruction can be performed at an earlier age without having to wait for adequate growth of rib cartilage.[7] Furthermore, donor site morbidity from harvesting rib cartilage is no longer a concern in alloplastic reconstruction. Ear reconstruction based on a porous polyethylene (Medpor, Porex Surgical) framework is now even considered the standard method of treatment for microtia by some surgeons because of the highly successful outcomes reported.

Here, we describe the specific surgical techniques involved in successful Medpor implantation and present recent

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advances in Medpor ear reconstruction that decrease complication rates. Our purpose is to outline the advantages and disadvantages of this form of alloplastic ear reconstruction in comparison to other methods of total ear reconstruction.

Goals and Challenges of Ear Reconstruction

There are several goals that must be kept in mind when considering total ear reconstruction in patients with microtia. Patients are first and foremost concerned with how well the reconstruction looks; in addition, they would like to know how long it will last. Surgery should be efficient and performed in as few stages as possible. The psychological repercussions of peer ridicule and bullying are also addressed due to its potential long-lasting effects. Through corrective surgery, children can reintegrate into society with uplifted self-esteem and can also wear glasses if necessary over the reconstructed auricle.

There must also be a cohesive and coordinated effort to restore hearing loss. Restoration is aimed to avoid detrimental delay in speech, cognition, and social interactions.[1] Based on the severity of microtia, associated abnormalities, and audiologic deficits, a multidisciplinary team comprised of pediatric plastic surgeons, otolaryngologists, otologists, and audiologists, and social workers can coordinate a plan for surgical reconstruction and hearing rehabilitation. Early in life, several options are available. Bone-anchored hearing aids (BAHA) are commonly used to restore hearing. Other options include cochlear implants and early canalplasty.

Bouhabel et al[8] found that hearing gain was higher after a combination of canalplasty and BAHAs than after surgery alone. Thus, patients who have undergone surgical correction of microtia and aural atresia may continue to have some degree of hearing loss that requires conductive hearing devices.

One of the primary challenges of total ear reconstruction is utilizing a method that not only manages the aesthetic components of microtia, but also serves to restore acoustic function in a reasonable time frame. Classically, autologous ear reconstruction and atresiaplasty are coordinated such that atresiaplasty is delayed until after the costal cartilage graft has been inserted into the postauricular skin pocket.[9] If atresiaplasty is performed prior to autologous repair, the mastoid tissue scars down and compromises the amount of viable tissue available for future autologous ear reconstruction.[9] Overall, this dual approach to microtia and aural atresia involves multiple-staged procedures that span over the course of a few years. Recently, Romo et al[10] found that reconstruction using a high-density porous polyethylene framework beneath a temporoparietal fascia (TPF) flap combined with implantation of a bone-anchoring hearing aid (BAHA) produced excellent aesthetic and hearing outcomes. This two-stage protocol is much less grueling for children compared with combined autologous reconstruction and atresiaplasty. Furthermore, a BAHA achieved more postoperative hearing gain (average 31.8 dB) than atresiaplasty (average 17.7 dB), suggesting that children can achieve appropriate aesthetic and functional hearing goals using Medpor reconstruction and BAHA placement without jeopardizing auricular integrity after an atresiaplasty.[11] In a retrospective case review, Roberson et al[12] found that the hearing gain in patients who had atresiaplasty before Medpor reconstruction was similar in patients who had atresiaplasty after autologous reconstruction. Therefore, patients can undergo early atresiaplasty for hearing restoration and early ear reconstruction with Medpor, while excluding donor-site morbidity involved in autologous repair. Lastly, there are microtia teams who are pushing the forefront with single-stage microtia reconstruction with canalplasty (CAM).

Achieving symmetry and appropriate size of the reconstructed ear can be especially challenging because it requires not only experience, but also extensive preoperative planning. Dimensional measurements and template drawings of the normal contralateral ear are useful in unilateral cases as they provide a guide for surgeons to model the reconstructed ear after.[13] However, ear symmetry and size is judged mostly clinically by physical appearance relative to overall facial structure, not just how closely the two ears match in regards to their dimensions.[14] A malpositioned ear can make reconstruction even more difficult because repositioning of the ear is limited by the location of the external auditory meatus.[7] Furthermore, a bulkier framework is needed to maintain long-term projection and definition of the ear; otherwise, a tight skin envelope over the ear construct and progressive scar contracture after the surgery will slowly diminish any of the fine details of the sculpted cartilage.[7]

Historical Approach to Ear Reconstruction

Ear reconstruction was initially performed using autologous grafts in the 1920s; since then alloplastic implants, and prosthetics have been introduced as additional options for ear reconstruction.[7] Each method has its own advantages and disadvantages that lead to surgeons favoring one method over another.

Autologous Reconstruction

Tanzer[3] pioneered the techniques for autologous ear reconstruction using rib cartilage. Brent,[4] Nagata,[5] and Firmin[6] later modified these methods to achieve finer results in fewer stages. For example, Brent[4] classically described autologous reconstruction in four stages approximately 3 months apart, while Nagata[5] combined the techniques into two total stages that consisted of harvesting and inserting the cartilage graft first, and then elevating the banked cartilage to create projection of the constructed ear. Nonetheless, autologous reconstruction is a lengthy process consisting of multiple procedures as well as donor-site morbidity and pain. The techniques themselves can be difficult to perform for nonexperienced surgeons and can leave visible scars. Overtime, the cartilage can resorb, leading to poor ear projection and loss of auricular definition.

The Nagata[5] technique tended to have more complications than the Brent[4] technique, such as framework exposure, infection, chest wall deformity, and pneumothorax.

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Nagata[5] used wires that had high extrusion rates to hold the cartilage framework together, whereas others used nylon sutures to limit extrusion. In addition, Nagata[5] recommended waiting until 10 years of age for his method of autologous reconstruction, in comparison to Brent's[4] recommendation of 6 years of age, to allow for the rib cartilage to achieve adequate amount of cartilage volume and stiffness.

Prosthetic Reconstruction

Prosthetic ear models made of silicone can be useful in patients who are not optimal surgical candidates or have poor surrounding tissue that is not useful for other methods of total ear reconstruction. In elderly patients or those who had auricular cancer resection, radiation, or trauma, prosthetic ears are an excellent alternative to surgical reconstruction.[15] The prosthesis can either be held in place by adhesive or titanium osseointegrated fixtures.[16] Overall, prosthetic ears can achieve very favorable aesthetic results as they appear realistic and have secure attachments to the head. The prosthetics can be modeled after the normal contralateral ear for appropriate symmetry, size, and projection.

Prosthetic ears can be disadvantageous because they are expensive and need to be replaced every few years due to silicone deterioration and color fading.[16] Prosthetic ear implants are artificial, so they have no benefits in hearing restoration. The sole purpose of prosthetic ears is to provide a realistic, aesthetically pleasing option for children with microtia or adults with acquired ear deformities. Prosthetic ears in children are primarily indicated as a salvage procedure when other methods of total ear reconstruction have failed, especially because children often refuse to wear the prosthetics and may not be mature enough to maintain the device hygiene required on a consistent basis.[7]

Alloplastic Implant-Based Reconstruction

In the 1990s, Cronin[17] published details on alloplastic ear reconstruction using nonbiologic Silastic ear implants. These implants promoted capsule formation, provided a poor vascular bed for overlying tissue flaps and skin grafts, and yielded high spontaneous extrusion rates.[18] Hence, autologous reconstruction was generally favored over alloplastic implant reconstruction as a better long-term option at the time. Reinisch described the early use of porous polyethylene in 1994. Early experience with the product showed a fair amount of reconstructive failures. Later refinement of the technique has lowered the complication rate by placing a temporoparietal flap over the Medpor construct for adequate soft tissue coverage.

After the popularization of this technique, porous polyethylene (Medpor) has become a comparable alternative to rib cartilage for total ear reconstruction for a variety of reasons.[7] Medpor-based reconstruction provides better ear definition and projection than traditional autologous reconstruction. Implanting the Medpor and achieving appropriate projection and symmetry involves only one- or two-staged procedures,[18] while autologous reconstruction not only requires tedious sculpting of the rib cartilage, it also involves 2- or 4-staged procedures depending on the technique used (Nagata[5] vs. Brent,[4] respectively). In addition, rib cartilage reconstruction typically requires an overnight stay for pain control.[13] Medpor reconstruction can be performed as an outpatient surgery with a relatively shorter postoperative recovery period.[19]

Patients who undergo autologous reconstruction with rib cartilage have a visible chest scar, chest wall deformity, or pneumothorax.[15] Medpor reconstruction does not involve this donor-site morbidity and can even be performed at a younger age. There is no period of waiting for a suitable-sized cartilage graft. The ear typically reaches 85% of its adult size by the age of 4 (►**Fig. 1**).[20] The average age of a child

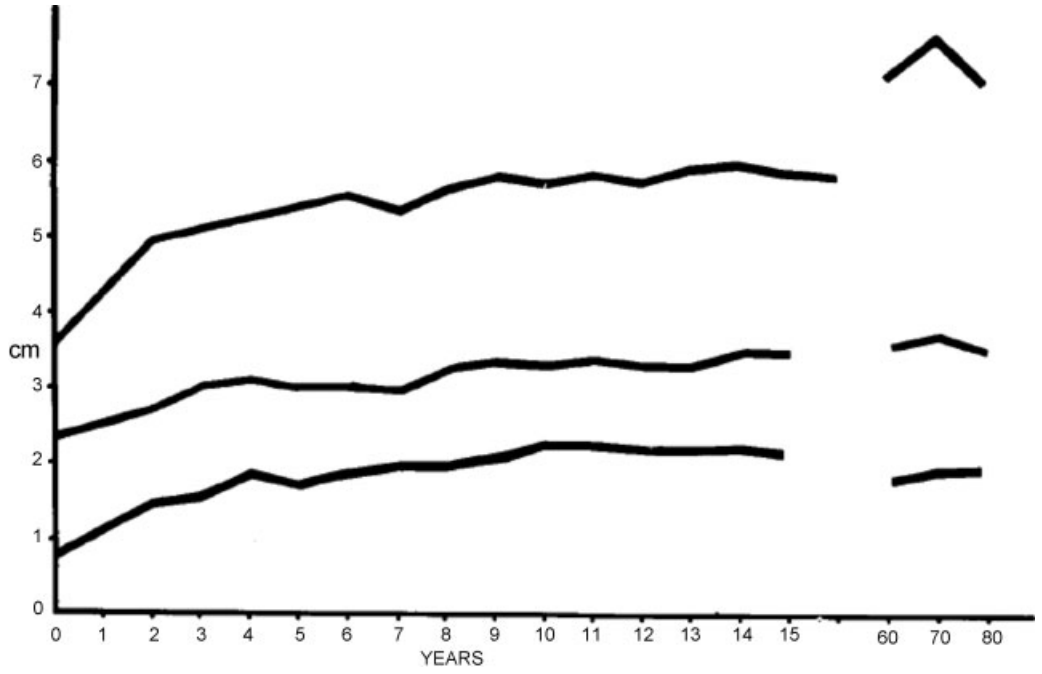

Fig. 1 The top line represents ear height, the middle line represents width, and the inferior line represents the mastoid-helical rim distance. (From Adamson JE, Horton CE, Crawford HH. The growth pattern of the external ear. Plast Reconstr Surg 1965;36(4):466–470.)

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(6–11 years) who has autologous ear reconstruction is typically older than the average age of a child (4–5 years) who undergoes Medpor reconstruction.[21,22] This younger age is well before school matriculation, so children can improve their ear appearance and possibly avoid teasing and social ridicule at school.

One of the major arguments against Medpor reconstruction is that porous polyethylene is a nonbiologic material that triggers some degree of immunogenicity.[2] The implant may not integrate as well as an autogenous cartilage graft from the rib, leading to high extrusion rates.[18] The Medpor framework can be exposed, fractured, or surrounded by an infection, which can all eventually result in failure of reconstruction.[14] Complications and outcomes of Medpor ear reconstruction are further discussed below.

Porous Polyethylene Implants in Ear Reconstruction

General Characteristics of Porous Polyethylene

Porous polyethylene is an inorganic, hydrophobic material commonly used in facial reconstructive procedures. The alloplastic product is highly biocompatible, durable, nonresorbable, and thermoplastic.[2] The host tissue produces a predictable, minimally inflammatory reaction to the framework and has revealed neovascularization of the construct.[2,23] Furthermore, there is limited bone in-growth or resorption compared with other alloplastic implant materials.[2]

Polyethylene comes in three different grades—low, high, and ultra-high—with higher grade indicating increased tensile strength.[2] High-density porous polyethylene is usually used in facial reconstructive and plastic surgery, while ultra-high porous polyethylene is used in orthopedic surgery for more load-bearing areas.[2,15] Polyethylene is a popular alloplastic material in reconstruction because it is firm and resists compression, yet is still mildly flexible. Medpor implants are prefabricated, but they can be contoured intraoperatively with heat or a scalpel into a shape custom-designed for the patient.[2] Medpor is difficult to mold compared with other alloplastic materials, but is just malleable enough to alter and contour to meet the patient's specific needs.

Pore sizes of polyethylene range from 40 to 300 μm.[15] The interconnecting porous structure permits fibrovascular integration of the patient's tissue into the polyethylene framework, which enhances implant stability and eliminates dead space at the recipient site. The vascular growth into the framework also helps prevent infection in theory by allowing for an appropriate inflammatory and immunogenic response.[2] Even when the porous polyethylene framework is exposed, the wound bed can generally heal well secondarily with low rates of infections.[13] The implant can be impregnated with antibiotics prior to implantation using a vacuum syringe, further reducing the risk of infection.[19] End-stage healing results in a fibroconnective tissue scar that surrounds the entire framework, adding to the durability of the implant.[2] This actually makes secondary removal of the implant difficult in situations of infection or framework fracture.

Table 1 Factors influencing porous polyethylene implantation[2]

Recipient tissue bed	Implant characteristics
Vascularity of surrounding tissue	Porosity and absorption of antibiotic solution
Thickness of soft tissue coverage	Texture of implant surface
Tension of soft tissue upon closure	Stiffness of framework
Size of recipient pocket site	Malleability and flexibility
Proximity to areas colonized with bacteria	Easy of contouring and reshaping
Tensile forces acting on soft tissue coverage	Adaptability and fixation to tissue bed

Successful implantation of a porous polyethylene ear framework depends on several factors (►**Table 1**).[2] The quality of recipient tissue, vascularity, and soft tissue coverage are important considerations when determining adequacy of the recipient site and surgical approach to implantation. Because of scarring from a prior surgery or oncologic radiation therapy in the area, the recipient tissue bed may be compromised with poor vascularity and a suboptimal immune response. This increases the risk of implant infection and failure. The single most important factor to success with Medpor implantation in ear reconstruction is the size and viability of the TPF flap. Ideally, the soft tissue covering the implant should be as thick as possible to decrease extrusion rates.[2] Ensuring adequate size of the recipient tissue pocket is also crucial to prevent significant tension upon soft tissue closure.

Uses of Medpor in Craniofacial Surgery

Porous high-density polyethylene has numerous uses in craniofacial surgery in both traumatic and cosmetic settings. Medpor can be used to contour and stabilize the facial skeleton, more specifically the orbital wall, temporal fossa, maxillary and mandibular bone, calvarium, auricle, and chin.[24] These implants provide support and protection to the underlying structures without donor scar and donor site morbidity from autologous bone or cartilage grafting. Polyethylene may actually be a better long-term and permanent option than bone or cartilage graft because bone can eventually resorb and cartilage can reform the deformity due to cartilage memory.[25] Medpor has excellent contouring abilities and a decreased risk of implant migration due to the fibrovascular network embedded into the framework. For example, chin augmentation and malar augmentation are safely and effectively performed using Medpor with low frequency of complications and high overall patient satisfaction; in fact, Medpor-enhanced chins and malar prominences feel firm and bone-like on palpation during long-term follow-up.[26]

Alloplastic materials are by all means not the ideal solution for craniofacial defects. Allogenic implants can be rejected by host tissue, infected, exposed, displaced, or

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fractured. Although Medpor implants possess these disadvantages, the utility of this material in facial reconstruction such as microtia outweigh the risk of relatively infrequent complications.

Considerations of Medpor Implantation in Ear Reconstruction

Total ear reconstruction using Medpor is indicated in children with microtia or those who have failed autogenous reconstruction attempts. There is no need to wait for rib cartilage growth and maturity, so Medpor reconstruction can be initiated as early as age 4 when the child's normal contralateral ear has reached 85% of its mature size.[20,21] Even though the normal ear will continue to grow slightly afterward, long-term data show that there is not too much of a discrepancy in size, rotation, and projection between the normal and reconstructed ears.[20] Families tend to prefer this approach because their children can undergo total ear reconstruction before school matriculation and avoid teasing remarks about a craniofacial defect. However, children this young may not be cooperative or mature enough to participate in the substantial postoperative care involved. These factors must be balanced when deciding on the timing of Medpor reconstruction to ensure successful implantation and outcomes for the child.

Medpor is an expedient alternative for autologous total ear reconstruction. Porous polyethylene implantation beneath a TPF flap and full-thickness skin graft is completed in less procedures and shorter operative times than autologous repair. The techniques involved to insert the implant, raise the TPF flap, and harvest a full-thickness skin graft can be as challenging as autologous costal cartilage grafting.[13] Because of a possibly simpler operative and postoperative process, Medpor implantation is used as the standard approach to total auricular reconstruction by many plastic surgeons.

Facial structures are highly vascular and tend to have plenty of collateral blood supply, which allows the reconstructed auricle to heal very well around the porous polyethylene construct. However, there are certain disadvantages associated with using alloplastic reconstruction of the auricle. For example, the implant can extrude or become exposed due to flap necrosis or skin graft failure.[13] Although porous polyethylene can be a permanent reconstructive option for children in theory, the framework can be displaced or fractured.[9] In addition, the need for a TPF flap for adequate soft tissue coverage over the implant sacrifices a salvage procedure for complicated framework infections. A contralateral TPF flap can still be utilized for salvage procedures, but Medpor reconstruction cannot be repeated once flaps from both sides have been utilized.

Surgical Techniques

Medpor reconstruction is completed in one or two stages.[19] If two stages are performed, the second stage is 3 months later and involves ear lobule transposition, tragus reconstruction, and occasionally deepening of the conchal bowl.[13] A BAHA can also be placed during the second stage if the child needs hearing amplification.[10] Most of the time, patients have good aesthetic results with just one operation for Medpor reconstruction.

Table 2 Aesthetic considerations when positioning the Medpor auricular framework[18]

Helical root is at the same horizontal level as the lateral canthus.
Superior helical rim is at the same height as the top of the eyebrow.
Lobule position is in line with the nasal tip.
Inferior border of lobule is in line with the spina nasalis.
Distance of lateral orbital wall to helical tip
Total width and height of the ear

Preoperative Examination and Planning

The preoperative planning process for Medpor reconstruction is similar to autologous reconstruction. A strong grasp on auricular anatomy and cephalometric ear parameters is necessary to evaluate ear deformities and successfully plan reconstruction.[13] The patient's ears are examined in regards to symmetry, size dimensions, rotation, projection, and position on the head relative to other facial structures (►**Table 2**). The earlobe has been described as a useful tool to translate symmetry, but it is the senior author's experience to not be the case.[7] The normal ear is traced on to a clear radiographic film and used as a mirror guide to shape the Medpor construct, and to position the ear relative to the lateral canthus, and nasal ala (►**Fig. 2**). This guide will also register the axis of the reconstructed ear. A measurement

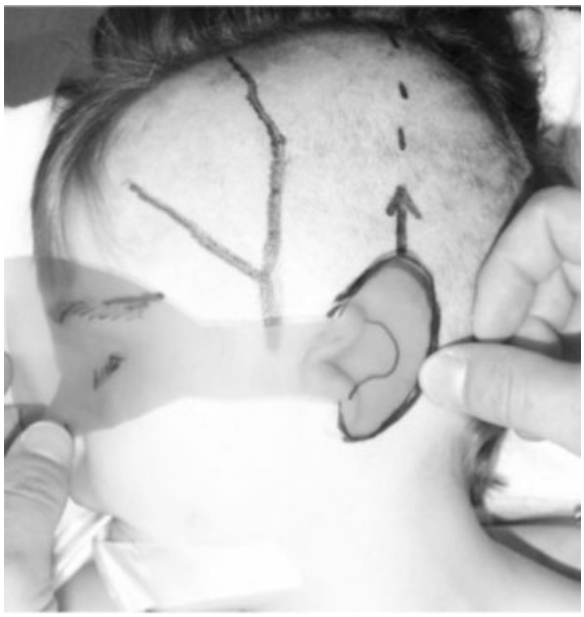

Fig. 2 Using X-ray film or plastic mask material, the normal ear's shape, size, and position are marked in relation to the eyebrow, lateral canthus, and alar base. The tracing can be flipped to the side of microtia as a guide for the axis of the constructed ear.

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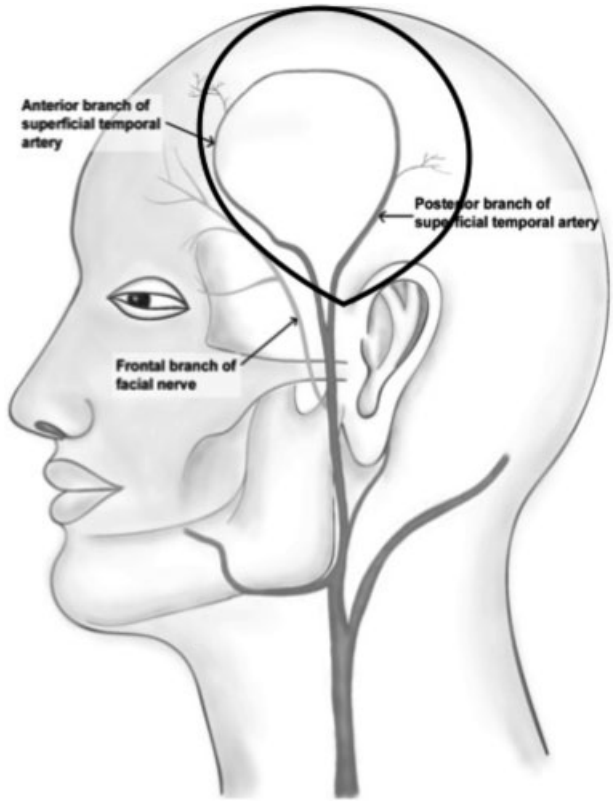

Fig. 3 The anterior branch travels just cranial to the frontal branch of the facial nerve. The anterior and posterior branches will tend to unite superiorly, so it is preferable to capture this linkage for improved vascularity of the temporoparietal fascia flap.

from the lateral canthus to the root of the helix (on the unaffected side) is used to mark the takeoff of the helix of the reconstructed ear. If both ears are affected, a parent's ear can be used as a model.[13] The position of the auricle on the scalp is marked; the anterior helix of the ear should sit approximately 6 to 7 cm from the lateral canthus, rotated posteriorly at a 20-degree angle from the vertical.[13] The superficial temporal artery (STA) branches are traced on the scalp, using Doppler assistance, to prepare for the TPF flap. It is important to also mark the path of the frontal branch of the facial nerve along the Pitanguy[27] line, which is approximately 0.5 cm from the tragus or the hair-bearing temporal skin in patients without a tragus to approximately 1.5 cm superolateral to the lateral eyebrow (►**Fig. 3**). The dimensions of the TP fascia flap are marked, 11 × 11 cm on the scalp.

The vascularity, recipient pocket size, and estimated thickness of the surrounding tissue should always be assessed. A pedicled TPF flap based off the STA provides approximately 1 to 2 mm of soft tissue coverage, and is an important facet contributing to low extrusion rates after Medpor reconstruction.[18] A Doppler probe is employed to identify and mark the anterior and posterior branches of the STA.[13] Computed tomography or magnetic resonance angiography can be useful in patients who have had prior surgery to identify the presence of a functioning artery.[13]

Medpor Construct Preparation

The polyethylene ear skeleton is comprised of two parts—a helical rim and an ear base (►**Fig. 4**). Usually, the film tracing of the ear model is scaled down by approximately 3 to 4 mm to account for the soft tissue bulk that will ultimately surround the Medpor framework, and to account for the lobule.[13] Porous polyethylene material is molded into the desired ear shape and size based on a template tracing or three-dimensional model of the normal contralateral ear. Refinements can be made to the Medpor intraoperatively using a scalpel per the discretion of the surgeon.[13] Both the rim and base elements are separately placed into a large syringe and impregnated with dilute iodine solution prior to soldering, in an effort to create an antibacterial effect. The rim and base elements are then fused together using a high-

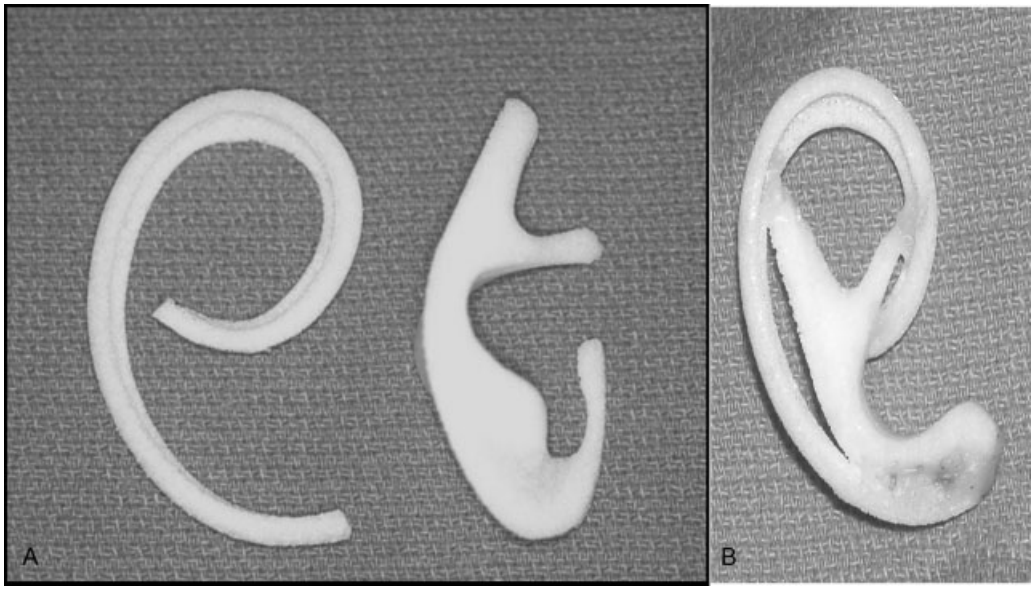

Fig. 4 Helical rim and ear base pieces of the porous polyethylene (**A**) are bound together to create the auricular framework (**B**).

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temp cautery device. Originally, the Medpor base design facilitated 3 points of fixation between rim and base. The newer generation of Medpor implants allows for 5 points of fixation between the rim and base, decreasing the risk of fracturing. Proper smoke evacuation is essential during this portion of the surgery.

In addition, the rudimentary cartilage of a microtic ear can be removed during surgery and sutured to the polyethylene construct to act as a tragus.[18]

Antibiotic Course

Patients should receive intravenous antibiotics preoperatively followed by oral antibiotics in the postoperative period to cover for *Staphylococcus aureus* and *Streptococcus epidermidis*. One gram of cephalexin or 600 to 900 g of clindamycin is typically used preoperatively.[2] The rationale behind preoperative antibiotic loading is to eliminate bacterial inoculation in the tissue bed and on the implant surface; however, large clinical trials have not provided substantial evidence confirming the clinical advantages of this approach.[2] The porous polyethylene construct is also soaked in additional antibiotic solution intraoperatively before implantation.[13]

Temporoparietal Flap Elevation

To harvest the TPF, Reinisch et al[19] initially used a "Y"-shaped incision. The incision was marked where the inferior tail of the "Y" was at the superior edge of the intended helix. The anterior extent of the "Y" incision proceeded approximately 10-cm superior to the intended helical rim, while the posterior extent proceeded approximately 5-cm posterior to the intended helical rim.[13] Helling et al[28] proposed an endoscopic approach to harvesting the TPF flap through a small 2- to 2.5-cm transverse incision in the scalp, which reduces visible scarring, alopecia, and surgical time in comparison to open surgery. Currently, the preferred incision is a transverse, lower temporal to mastoid approach, which spares the scalp.

Once the incision is made down beneath the level of the hair follicles, the temporoparietal fascia is exposed. The TP flap is dissected on its anterior surface. Use of retraction, good lighting, loupe magnification, and suction are recommended. Care is taken not to damage the subdermal plexus vessels.[13] To ensure adequate coverage over the entire Medpor framework without tension or tenting, the TPF flap should measure at least 11 cm in width and 11 cm in vertical height from the midconcha.[19] If present, the flap should include both the anterior and posterior superficial branches of the STA, including the looped connection that often occurs in the superior temporal scalp. The most superior few centimeters of the flap are best dissected after posterior undermining, to allow for tenting of the flap, increasing visibility around the convexity of the cranium. (The posterior undermining technique will be described.) The anterior border of the flap is separated from the deep temporal fascia caudal to the anterior branch of the STA. If this flap inclusion encroaches into the pathway of the frontal branch of the facial nerve, only the lower portion of the anterior branch is included in the flap[19] however, this is rare, and most flaps can contain the anterior branch. The flap also incised along the posterior border. A urethral sound is introduced under the anterior and posterior aspects of the flap with undermining of the undersurface. The intent is to include the subgaleal fascia in the flap, this two-layer flap adds bulkier soft tissue coverage over the Medpor framework, decreasing the risk for implant extrusion.[19] Once this is done, the distal anterior dissection can be completed. The flap is then delivered through the inferior temporal incision by transecting the remaining anterior, posterior, and distal edges. Following initial inferior delivery, the flap is returned to its original pocket to rewarm, and allow for vessel dilatation.

Treatment of Local Skin and Vestigial Cartilage

The local skin and cartilage must be prepared properly to accept the Medpor implant and TP fascia for ear construction. First, the local skin anterior to the flap elevation incision is elevated. Laterally, it is converted to a thin full-thickness skin graft, medially, a thin pedicle is left behind. During elevation of the local temporal skin, the vestigial cartilage will be encountered. It is skeletonized from the local soft tissue and removed. A portion of this cartilage can be banked in a subcutaneous pocket for use at a second stage for tragal reconstruction. The lobule is marked and elevated. Two 4-mm TLS drains are inserted, exiting in the lateral neck. One underlies the Medpor construct, the other the flap donor site.

Ear Assembly

After flap elevation, construct formation, and local tissue preparation, the ear is assembled. The TP fascia flap is first delivered through the lower temporal incision. The viability and vascularity of the TP flap is assessed. Next, the fabricated Medpor construct is placed into the ideal position overlying the first drain, the flap is draped over it, and suction applied to the drain. The TP flap should then shrink-wrap over the Medpor and achieve its contour. With an airleak, or ill-defined contour, reposition the TP flap until proper contour is achieved without a leak. No sutures are necessary to fix the framework into place; the framework usually maintains its position through soft tissue suction only.[19]

Skin Graft Harvest and Preparation

Frequently, the local skin of the microtic ear and mastoid is only enough to cover the lateral surfaces of the implant (►**Fig. 5**).[13,18,19] A full-thickness skin graft is harvested from one or more donor sites to provide added coverage for the reconstructed ear. The contralateral non-hair-bearing retroauricular skin is commonly used to cover the anterior or lateral surfaces of the implant due to good color-match (►**Fig. 6**).[13,18,19] The postauricular surface of the reconstructed ear and normal ear is covered by a full-thickness skin graft taken from the abdominal wall, or groin region.[14,19] The darker pigmentation of these grafts can be tolerated posteriorly as there is a natural shadow in this region. In bilateral cases, inner arm skin is the preferred coverage for the anterior ear. A split-thickness skin graft from the scalp can be used to avoid donor-site scars, but there is a risk of contraction and development of small inclusion

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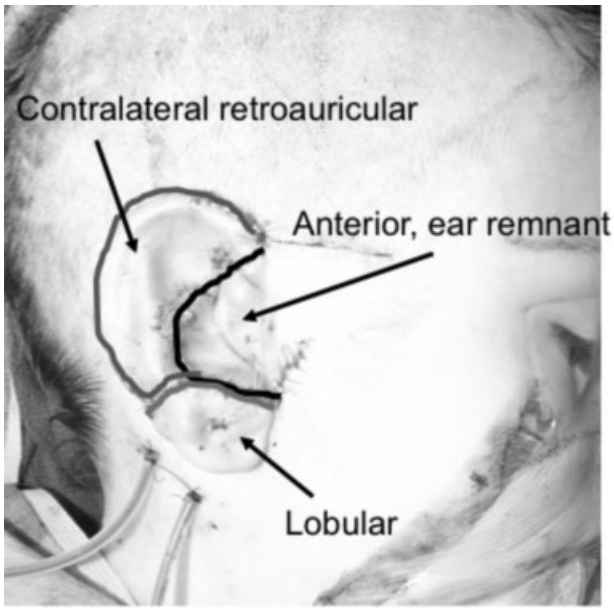

Fig. 5 The anterior skin remnant and lobular portions can be used to cover lateral surfaces of the implant. Contralateral retroauricular full thickness skin grafts are often required to ensure complete coverage of the Medpor ear construct.

cysts.[13] Therefore, a split-thickness skin graft is used primarily in patients who need a second-stage procedure, during which the sulcus contracture can be released and replaced with a full-thickness skin graft if necessary.[13]

Rapidly dissolving sutures are used to suture the skin grafts over the TPF flap.[13] Air should be expressed from beneath the graft and TPF flap, all layers ultimately in contact with each other.[19] The reconstructed ear and incisions are covered with antibiotic ointment. Soft silicone putty is molded over the graft and polymerizes when exposed to air.[18,19] This prevents swelling without exerting excessive compression on the graft and flap.[18,19] Another method would use drains, with prep sponges cut to accentuate contour, instead of the silicone putty. Finally, a protective, firm, plastic ear cup is placed over the mold.[19] Drains are usually injected with a long-acting anesthetic and connected to bulb suction to prevent seroma formation.[19] Surgeons should expect excess projection of the framework immediately after surgery, but the implant tends to settle down in place over time.[13,18,19]

Alternative Techniques

Soft tissue expanders can be placed underneath the mastoid skin or scalp skin to gradually increase the length and laxity of local skin available for ear reconstruction.[15] The rationale for using soft-tissue expanders is that this allows for complete skin coverage over the Medpor framework in cases of severe anotia, failed autologous repairs, or posttraumatic cases.[9] Our experience reveals that this is usually not the case. Kludt et al[29] show that prolonged soft tissue expansion of the non-hair-bearing mastoid skin ($\sim$ 60 mL) permits robust coverage over the reconstructed ear. The expanded skin is sufficient to drape over the Medpor framework without having to harvest a TPF flap or skin graft, which reduces operative time and morbidity and allows for a natural appearing, aesthetically pleasing ear. However, the skin may end up being too thin to cover the Medpor framework, increasing the risk of extrusion.[19]

Porous polyethylene can also be used as a skeletal framework for tissue engineered-cartilage to adhere and integrate into. O'Sullivan et al[30] demonstrated that porous polyethylene with surrounding porcine auricular chondrocytes showed consistent neocartilage integration. The tensile strength of the auricle made from this neocartilage-enforced Medpor framework was superior to that of a normal Medpor-reconstructed auricle.[30]

Postoperative Management

Total ear reconstruction using a porous polyethylene implant can be performed with a one-night hospital stay or as an outpatient surgery. The drains are typically removed on postoperative day 5 to 7.[19] The silicone ear mold (if used) is removed 7 to 10 days postoperatively.[19] The plastic ear cup is still used for 2 to 4 weeks for protection against trauma to the framework, flap, or graft.[13,19] Care must be undertaken to ensure that the plastic cup itself does not cause

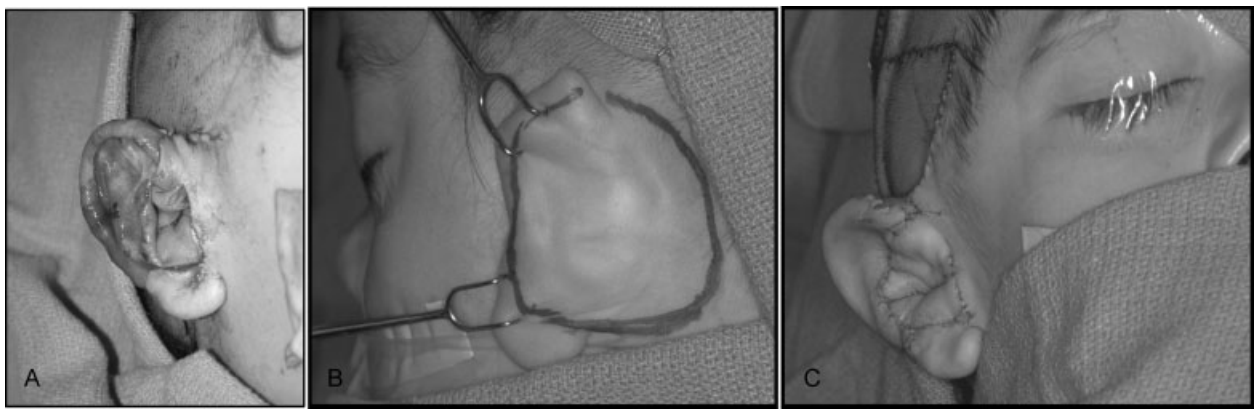

Fig. 6 Local skin flap placed over the anterior portion of the reconstructed auricle, but a significant portion of the ear still requires coverage (**A**). Full-thickness skin graft is harvested from the contralateral non-hair-bearing retroauricular sulcus, with markings for the incision shown (**B**), to provide soft tissue coverage over the defect. Skin graft is sutured into place to complete reconstruction (**C**).

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compression ischemia of the TPF flap. Patients are also given activity limitations to protect the framework and TPF flap.

Complications

Acute complications of Medpor reconstruction include hematoma, infection,[13] and flap loss. Hematomas can be drained in the office as needed. Infection is rare in the acute setting, usually a cellulitis, and is more associated within the subacute timeframe with exposure. Flap loss would be diagnosed by nontake of skin grafts at the first dressing change 5 to 7 days after surgery. The safest course of action is to remove the implant, and debride the necrotic flap and skin grafts. After a period of healing, an ipsilateral occipital fascial flap or contralateral free TPF flap can be utilized as a salvage procedure. Subacute complications include implant exposure with bacterial contamination, and with or without infection.

In general, an implant infection, a result of implant exposure, typically involves a strongly adherent biofilm surrounding the implant that is usually impenetrable by oral and intravenous antibiotics.[2] Treatment is guided by the type of exposure—a limited exposure with good seal and vascular cover elsewhere can heal with a small turnover flap (a "dry" exposure). If the wound is not sealed, and there is bacterial contamination evidenced by granulation tissue peel around the implant, the implant will have to be removed (a "wet" exposure).

In exposures with a biofilm around the implant without infection, the old implant is removed, granulation tissue debrided, and a new implant is fashioned immediately to preserve the ear and soft tissue architecture. An infected sinus tract extending from the Medpor implant can also drain frank pus.[31] In such cases of purulent implant infection, explantation is recommended.[2] Secondary removal of the implant is difficult because of the fibrovascular tissue integration into and around the auricular Medpor framework.[2] Surgeons should wait until the purulent infection and inflammation of the surrounding tissue has completely resolved before considering reimplantation.[2] Salvage of the implant is possible by aggressive irrigation, scrubbing, and debridement of the recipient site, as well as sterilization of the implant prior to reimplantation.[2] However, patients will have to be on a prolonged postoperative antibiotic course and will have a risk of infection recurrence. There are subacute cases in which the implant is exposed without a bacterial biofilm and granulation tissue. In these situations, minor debridement and a local turnover flap typically suffice to treat the problem, thus salvaging the implant. Defects less than 1 cm can heal by secondary intention because the implant has fibrovascular integration into deep pockets of the framework, allowing for inflammation and a healing response.[2,13] A local advancement flap or additional full-thickness skin grafts can be harvested to cover the defects, but if there is not much soft tissue integration into the Medpor framework, the flap or skin graft will likely be lost.[13] In such scenarios of framework exposure, the implant can be salvaged by harvesting a TPF flap, deep temporal fascia flap, or local skin flaps to completely cover the open reconstructed ear.[32] Appropriate wound care is crucial to safely preserve the framework and prevent further exposure. The added bulky soft tissue coverage from a local skin flap may decrease the definition of the reconstructed auricle, but this may be a better alternative than losing the entire reconstructed ear.[32]

Long-term complications include fracture of the construct. In the case of breakage, the old implant can be removed from the vascular pocket, with a new one immediately fashioned and inserted.

The framework can also be exposed if the overlying flap and skin graft are damaged or stretched due to trauma or compression. The risk of exposure is increased if the patient had a prior atresiaplasty because this would lead to scarred, poorly perfused mastoid skin that would alter viability of a local flap. Romo et al[13] and Cenzi et al[33] both reported a 4 to 6% complication rate among over 250 cases of Medpor ear reconstruction. The authors of both studies found that ensuring complete flap coverage of the framework was the most important factor in preventing acute complications, such as infection and extrusion.

Other complications include hair growth on the reconstructed ear and focal scalp alopecia in the native location of the flap.[19] A laser can be used to remove hair growth. The focal alopecia relates to hair follicle damage during TP fascia flap harvest. There may be poor texture and color match between the full-thickness skin graft and surrounding skin, especially if the graft was taken from the abdomen or groin.[13,18]

Outcomes

In general, auricular reconstruction with Medpor provides a good size match with the contralateral ear, especially

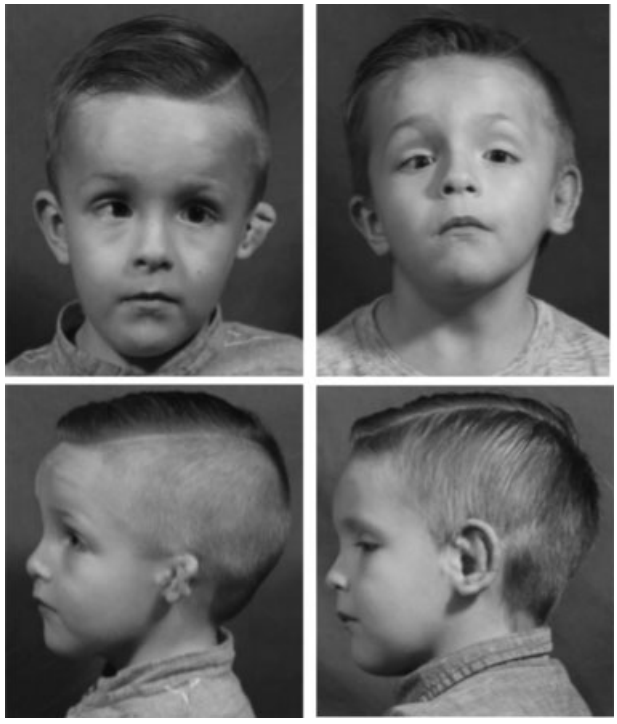

Fig. 7 Preoperative appearance (left column) and postoperative results (right column) in a 4-year-old boy with unilateral left microtia who underwent total ear reconstruction with porous polyethylene in one stage.

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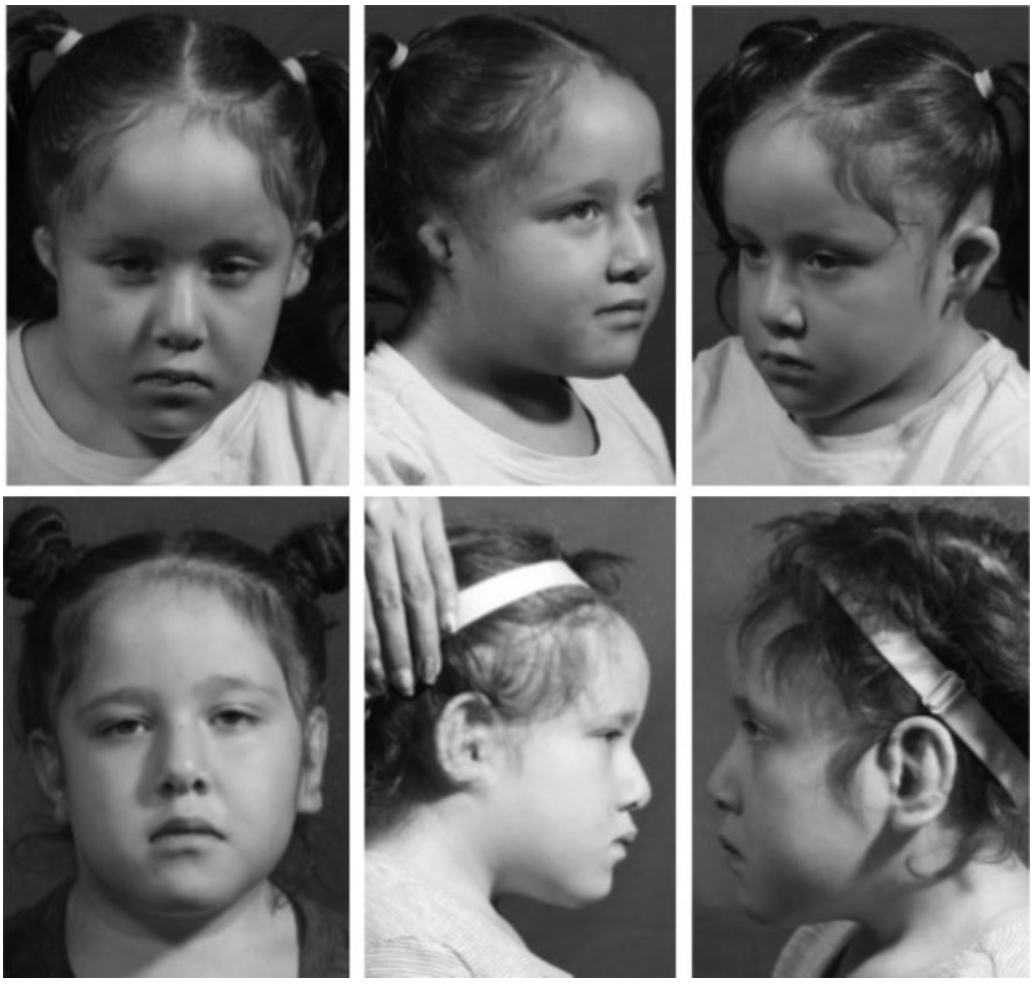

Fig. 8 Example of almost natural-appearing Medpor-reconstructed ears in a patient with bilateral microtia, with preoperative (top row) and postoperative (bottom row) facial profile shown in three stages.

because the porous polyethylene construct can be contoured and molded intraoperatively based on the patient's anatomy (►**Figs. 7** and **8**).[9] The reconstructed ear appears almost natural with good definition of the conchal bowl, helical rim, and antihelical fold. Over time, the patient may experience poor ear projection if the framework is displaced. The framework can also be fractured from trauma, particularly in highly active children. However, the complications associated with Medpor have drastically lowered over time.[19] Through Reinisch et al's[19] modified technique that incorporates a TPF flap for soft tissue coverage, the exposure rates in Medpor reconstruction have decreased from 44% to 7.3%. Fracture rates of the Medpor framework also decreased from 25% to 2.7%.[19] In a prospective study using validated questionnaires to evaluate quality of life and patient satisfaction after Medpor total ear reconstruction, Braun et al[34] found that quality of life improved in 75.6% of adults and 100% of children; 72.7% of adults and 85% of children were happy with their aesthetic results.[34] It is important to note that patients who had acquired auricular defects were twice as likely to be dissatisfied with the aesthetic results of reconstruction compared with patients with congenital auricular malformations.[34]

Conclusion

Total ear reconstruction with porous polyethylene implants is an excellent alternative to traditional autologous rib cartilage reconstruction. Medpor is a highly durable, biocompatible, nonresorbable, and minimally reactive material used in craniofacial reconstructive surgeries with favorable long-term stability. Using modified techniques pioneered by Reinisch,[19] surgeons can successfully perform Medpor reconstruction as early as age 3 with low rates of infection and extrusion. Placing an overlying TPF flap and full-thickness skin graft enhances the soft tissue coverage over the Medpor implant, providing adequate strength and protection to reduce complication rates. Therefore, Medpor is becoming increasingly popular in auricular reconstruction because of superior cosmetic results, fewer complication rates, and shorter postoperative recovery times. Some surgeons even consider Medpor-based auricular reconstruction to be the standard of treatment for children with microtia.

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